DIRECTION FINDING SYSTEM FOR SPREAD SPECTRAL PILOT SIGNALS FROM MULTIPLE MICROWAVE POWER RECEIVING SITES

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1. Introduction

SPS (Solar Power Satellite) transmits electric power generated by solar cells through microwave. Microwave power is sent to a power-receiving site. The retrodircetive array is generally used for this. The present paper proposes a new direction finding system to be used for a microwave power transmission system, which can send the power to multiple directions. The spread spectrum (SS) modulation is used for the signals in order to differentiate them. Power receiving sites send pilot signals and high power microwave beams are sent to arrival directions of the signals. This system is a kind of software retrodirective array.

A concept of this system is shown in Figure 1. Pilot signals are sent from energy receiving sites. The power is sent to the directions of the pilot signals. Because the direct sequence spread spectrum is used for the signals, this does not respond to erroneous signals and is more reliable under noises. This is a useful technique even for a single receiving site.

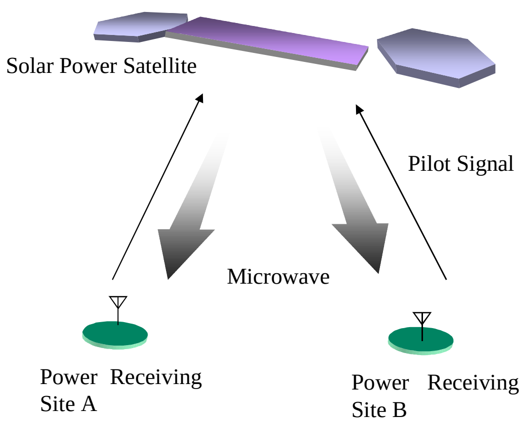


Figure 1. System Concept.

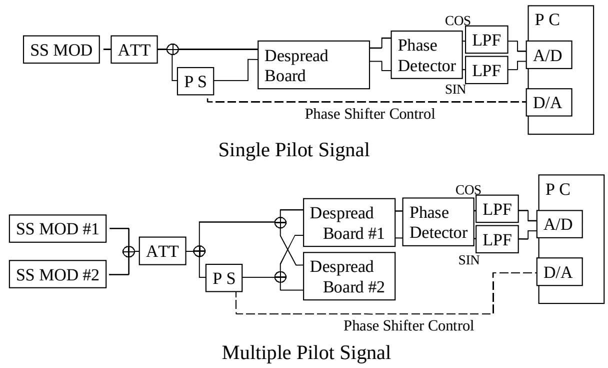


Figure 2. Block Diagram of Wired Experiment.

2. A direction finding system for multiple spread spectrum signals

The solar power satellite receives multiple SS pilot signals by more than two antennas and they are despread by pseudo-nose (PN) codes corresponding to the SS signals to obtain original signals. The information for arrival directions can be obtained from the phase difference of the original signals. Though the timing difference of the PN code can also be used to find the directions, the carrier phase is more sensitive because the carrier frequency is much higher than the PN code modulation speeds. The original signal can be modulated because the phase difference can be measured if the bandwidth of the filter after the despreading is wide enough for the modulation.

Encrypted information of the receiving site and useful information to control the beams like wave intensities at the receiving site can be modulated. The SS modulation has some secrecy. The encryption for information of the modulation makes the system more secure. Although Fujino et al. did a similar experiment [1], they used a single SS pilot signal and send the PN code clock for the synchronization of the received SS signal.

The PN codes used for the SS are not necessarily different. The same code can be used if their timing is different. The cross-correlation between the different timing with the same code is generally less than that between different codes. This concept is used as the soft handoff in the IS-95 CDMA system. In order to avoid using the same timing and synchrone the chip rate, GPS can be used. Since the number of multiple signals is not expected to be large, a single PN code, or M-series code, will be used. This system needs not to prepare for multiple frequencies of multiple codes. This simplifies the whole system.

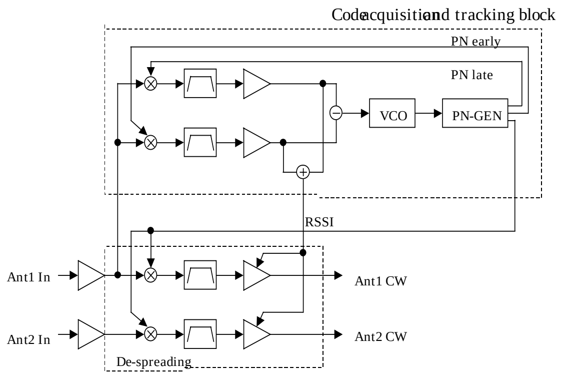


Figure 3. Block Diagram of Despread Board

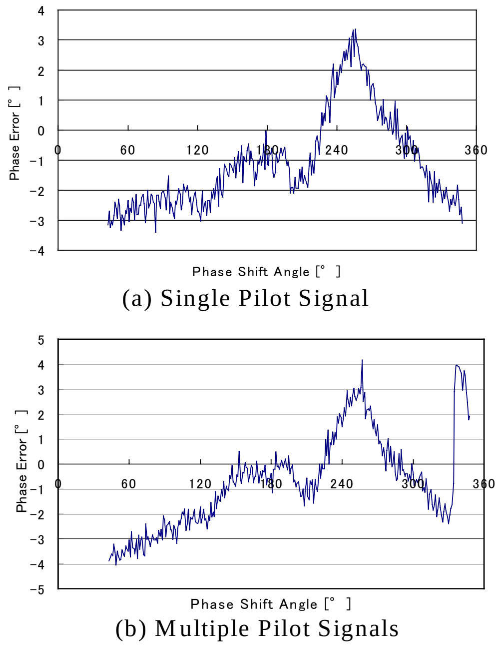
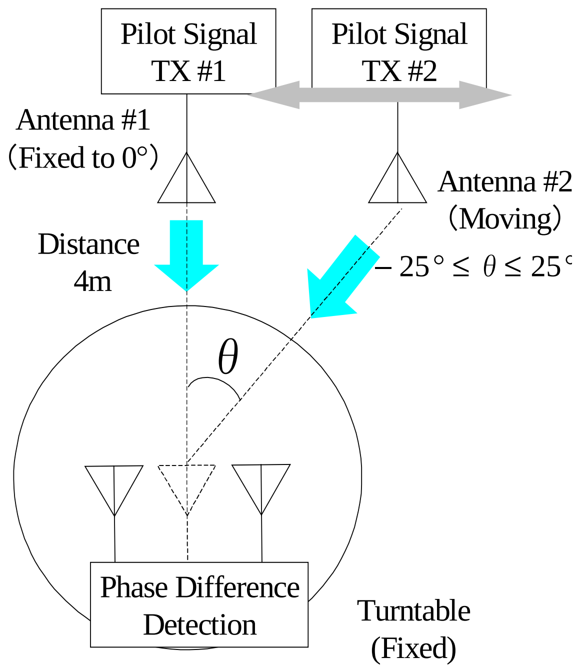


Figure 4. Results of Wired Experiments.

3. Experiments

An evaluation of the system is performed for two single pilot signals. The block diagrams of the experiment system and the despread board is shown in Figure 2 and 3, respectively. The phase shifters (PS) in Figure 2 simulate the phase differences between two antennas. Two outputs of the antennas are input to the RF and local terminals of the ring modulator and a tangent of the phase is calculated from sine and cosine components. Two SS signals are combined and the arrival directions of the two are the same in this case. The despread boards have a circuit to avoid to synchronize with the same timing as other board. The chip rate is 1.25 Mbps, the carrier frequency is 10.7 MHz and a 5-bit Maximum length code (the length of 31, 5-3 tap) is used in the experiments. If the chip rates of the two signals are not the same, the system does not work well because there are some occasions when the timings of the two codes coincide each other. Examples of the phase difference measurements for one and two pilot signals are shown in Figure 4 (a) and (b). The errors were ±3 and ±4 degrees for the cases of one and two pilot signals, respectively. Since one signal is a noise for the other in the two-signal case, the errors have increased.



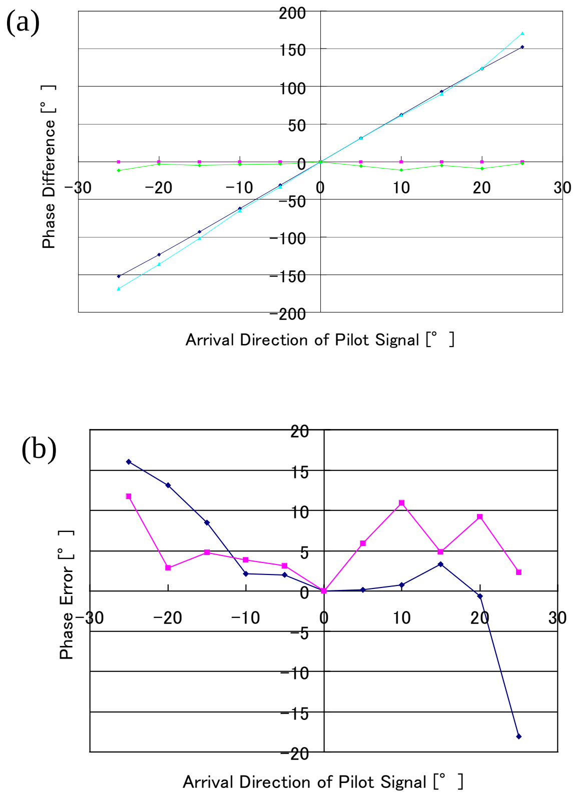


Figure 5. Configuration of Wireless Experiment. Figure 6. Results of Wireless Experiment.

Wireless experiments for two SS pilot signals with 904 MHz were also done in an anechoic chamber in the configuration shown in Figure 5. One signal is fixed to the front in the distance of 4m and the other moves in the perpendicular direction. The arrival directions of the latter correspond to ±25 degrees. The center among the three receiving antennas with half wavelength spacing is intended to be a reference antenna. As a local signal input of the phase detector, the output of a signal generator at a little different frequency from the pilot signal obtained better result than that of the reference antenna. This is because the output phases of the double balanced mixer used in the experiments depend on the intensities of the RF and local terminals and the S/N ratio of the signal generator is better than that of the received reference signal. An example of the results is shown in Figure 5. Figure 5(a) and (b) show the phase differences and their errors as a function of arrival direction, respectively. The linear lines in (a) show the expected values and the other lines are the results. Although the errors converted to the arrival directions are much smaller, they are more than the previous results.

4. Discussion and Conclusions

It is confirmed that the new direction finding system for multiple spread spectrum pilot signals works well. Phase difference can be measured by despreading the SS modulated signal. The same PN code is used to simplify the system. The timing of the code identifies pilot signals. Although the length of the code used in the present experiments is 31, it is not difficult to extend this.

One cause of the errors is the characteristics of the present ring modulator. Its output depends of the input intensities of the RF and local input different from the ideal. If the amount of errors are random when the number of the antenna elements, the errors of the beaming directions are relatively small. If they are systematic, the errors are very large. Further evaluation of the system is under way.

Beam forming for transmitting power to multiple directions is also important topics and we are studying this as well. In communications, the beams are sent to multiple points and nulls are directed to interference directions. In the power transmission, the beams are sent to areas, and not points. The power density of the beam and side lobe levels must be less than a certain level from a viewpoint of bio-effects and EMC. A new design concept is required for this application.

Acknowledgements.

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References.

[1] Y. Fujino, M. Ishii, and M. Fujita, Fundamental experiment of an incident angle detection system for power transmission beam control of a stratosphere radio relay system (in Japanese), Trans. IEICE B-II, vol. J80-B-II, no. 9, pp. 800-804, 1997.